Light meson spectroscopy with the KLOE experiment.

The KLOE collaboration presented by B. Di Micco [a],

[a] *Dipartimento di Fisica dell'Università "Roma Tre" e Sezione INFN, Roma, Italy.*

Abstract

In this paper we describe the status of the analyses in progress on light meson spectroscopy in the KLOE experiment. We present the analyses of ϕ decays into $f_0(980)\gamma$ and $a_0(980)\gamma$, the Dalitz plot analysis of the $\eta \to \pi^+\pi^-\pi^0$ decay, the branching ratio measurement of $\eta \to \pi^0\gamma\gamma$, the upper limits on $Br(\eta \to 3\gamma)$ and $Br(\eta \to \pi^+\pi^-)$, the measurement of the ratio $Br(\phi \to \eta'\gamma)/Br(\phi \to \eta\gamma)$ and ϕ leptonic width measurements.

1 Introduction

The KLOE detector [1], operates at the Frascati e^+e^- collider DAΦNE [2], which runs at a CM energy W equal to the ϕ-meson mass, W~1019.5 MeV. The analyses presented here are based on data collected in the years 2001 and 2002 for an integrated luminosity of $\sim 450\ pb^{-1}$ corresponding to 1.5 billions of ϕ and 20 millions of η mesons [Br($\phi \to \eta\gamma$) $\sim$ 1.3% [3]]. This means that KLOE can also study η physics in a clean environment with high statistic.

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[2] Corresponding author: B. Di Micco, Università "Roma Tre", Via della Vasca Navale, 84, I-00146, Roma, Italy, e-mail dimicco@fis.uniroma3.it

2 Search for $\phi \rightarrow f_0\gamma$ in $\pi^+\pi^-\gamma$ events.

The ϕ radiative decays to scalar mesons, $\phi \rightarrow S\gamma$, give significant insight in the assessment of the nature of lower mass scalar mesons [4]. With the KLOE experiment the decays $\phi \rightarrow f_0(980)\gamma$ and $\phi \rightarrow a_0(980)\gamma$ are searched for in $\pi^0\pi^0\gamma$ and $\eta\pi^0\gamma$ [5,6] final states respectively. Moreover the $f_0(980)$ signal is also searched for $\pi^+\pi^-\gamma$ events with a photon at large angle. The search for this signal is characterized by the presence of a huge irreducible background due to the initial state radiation (ISR), to $e^+e^- \rightarrow \pi^+\pi^-\gamma$ (FSR) and $\phi \rightarrow \rho^{\pm}(\rightarrow \pi^{\pm}\gamma)\pi^{\pm}$. The f_0 events are searched for in the large photon angle region $45^o < \theta < 135^o$ to reduce ISR background. The f_0 signal appears as a bump in the $\pi^+\pi^-$ invariant mass $M_{\pi\pi}$ spectrum around 980 MeV. Fig.1 (top) shows the spectrum obtained at $\sqrt{s} = M_\phi$.

An overall fit to the spectrum has been done by applying the following formula:

$$\frac{dN}{dM_{\pi\pi}} = \left[(\frac{d\sigma}{dM_{\pi\pi}})_{ISR} + (\frac{d\sigma}{dM_{\pi\pi}})_{FSR+f_0} + \right.$$
$$\left. + (\frac{d\sigma}{dM_{\pi\pi}})_{\rho\pi} \right] \times L \times \epsilon(M_{\pi\pi})$$

with L the integrated luminosity and $\epsilon(M_{\pi\pi})$ the selection efficiency as a function of $M_{\pi\pi}$. The f_0 amplitude is taken from the kaon-loop approach [7]. A forward-backward asymmetry $A = \frac{N^+(\theta>90^o) - N^+(\theta<90^o)}{N^+(\theta>90^o) + N^+(\theta<90^o)}$ is expected, due to the interference between FSR and ISR[8]. Fig.1 (bottom) shows the asymmetry as a function of $M_{\pi\pi}$ compared to the prediction based on the ISR-FSR interference alone. A significant deviation from the prediction is observed in the high mass region clearly due to the f_0 contribution.

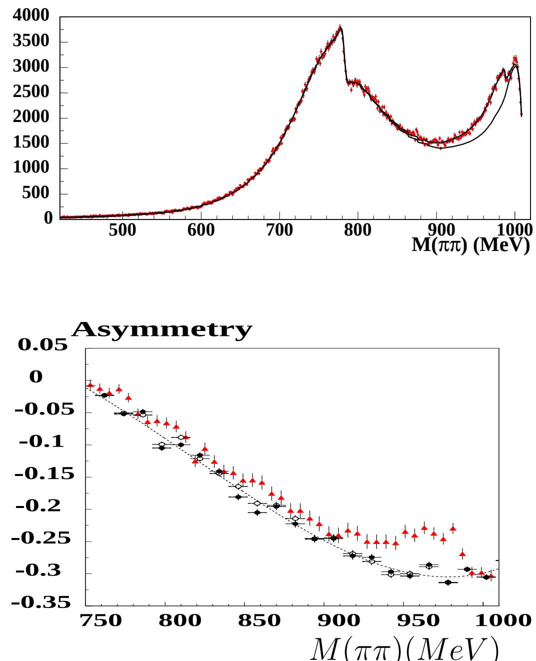

Fig. 1. (top) $M_{\pi\pi}$ spectrum of $\pi^+\pi^-\gamma$. The upper (lower) curves are the result of the fit and the estimated background due to ISR, FSR and $\rho\pi$. (bottom) Forward-Backward asymmetry A as a function of $M_{\pi\pi}$. The curve and the black points are the Montecarlo expectations based on the interference between FSR and ISR only. The experimental data are reported as triangles.

3 Dynamics of $\eta \rightarrow \pi^+\pi^-\pi^0$

The dynamics of the $\eta \rightarrow \pi^+\pi^-\pi^0$ decay has been studied with a Dalitz plot analysis. The conventional variables X and Y are defined as: $X = \sqrt{3}\frac{T_+ - T_-}{Q_\eta}$, $Y = \frac{3T_0}{Q_\eta} - 1$, where $Q_\eta = m_\eta - 2m_{\pi^+} - m_{\pi^0}$ and T_+, T_- and T_0 are the kinetic energies of the particles. The measured distribu-

tion has been fitted as: $|A(X,Y)|^2 \simeq (1+aY+bY^2+cX+dX^2+eXY+...)$. C-parity conservation prevents odd powers in X being present in the expansion: thus parameters c and e should be zero as confirmed by our fit. The results of the fit are shown in table 3 Efficiency is $\sim$ 36 % over the whole Dalitz plot. The evaluation of systematic effects is under completion.

Table 1
Fitted parameters P(χ^2) = 52 % of $\eta \to 3\pi$ Dalitz plot.

a	b	c
$-1.075 \pm .008$	$.118 \pm .009$	$-.0005 \pm .004$
d	e	f
$.049 \pm .008$	$-.004 \pm .01$	$.13 \pm .02$

4 Rare and forbidden η decays ($\eta \to \pi^0\gamma\gamma$, $\eta \to \pi^+\pi^-$, $\eta \to \gamma\gamma\gamma$)

The $\eta \to \pi^0\gamma\gamma$ decay is interesting to test the Chiral Perturbation Theory prediction for the branching ratio and $m_{\gamma\gamma}$ spectrum[9,10]. The most accurate measurement for the branching ratio[11] is, infact, far from any theoretical prediction for this decay based on ChPT. Recently a new measurement has been performed [12] giving a much lower value than the previous one, with a larger error. All previuos experiments were done at hadron machines, using mainly $\pi^- p \to \eta n$, and are largely dominated by $\pi^0\pi^0$ background and geometrical acceptance. KLOE performs a measurement of competitive precision in a cleaner environment. Furthermore, it has different background topologies and experimental systematics. The signal is searched for by looking for a $\pi^0\gamma\gamma\gamma$ topology, where the further γ comes from $\phi \to \eta\gamma$. Five prompt clusters are required and an overall kinematic fit requiring π^0 mass is performed. The clusters energy must be > 30 MeV and azimutal angle $> 21°$ to reject fake clusters coming from machine background. The dominant background channel is $\eta \to 3\pi^0$ that had been reduced with several topological cut. With this selection we obtain an efficiency of 5.7%. To give an idea of the sensitivity, In fig. 2 we compare the $M(4\gamma)$ data spectrum with MC based predictions of signal and background in two hypothesys for the size of signal: one based on PDG value[11] and one based on the recent CB result[12]. It is evident that our data are incompatible with [11] and are marginally in agreement with [12]. The background simulation and the efficiency for the signal is still under study.

$\eta \to 3\gamma$ decay is C violating. It is a sensitive test of C violation in the strong and electromagnetic interactions. For the details of this analysis see ref.[13]. The KLOE result for the branching ratio is: $Br(\eta \to \gamma\gamma\gamma) \leq 1.6 \times 10^{-5}$ @90 % C.L. This limit is the best experimental limit for this decay. The expected branching ratio from the Standard Model is $\leq 10^{-12}$ [14], so any discovery of a larger decay rate would be a clear signal of Standard Model deviation.

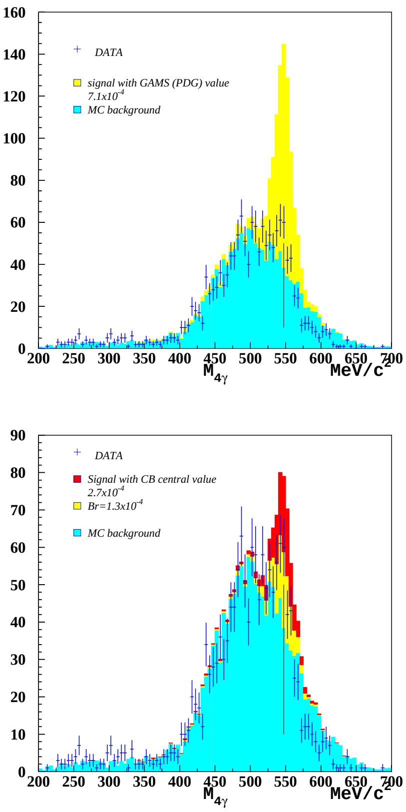

Fig. 2. M(4γ), the spectra expected from the GAMS[11] and Crystall Ball[12] measurement are shown. In the lower plot we show also the expected spectrum for a $Br \sim 1/2$ of C.B. result.

$\eta \to \pi^+\pi^-$ decay is P and CP violating. This decay is allowed as a weak direct CP violating decay with a very low branching ratio: BR($\eta \to \pi^+\pi^-$)$\sim 10^{-27}$ [15]. Therefore the detection of this decay at an accessible level would be a signal of P and CP violation not explainable in the Standard Model framework. The latest published [16] direct search of this decay has given the following 90% C.L. upper limit: $BR(\eta \to \pi^+\pi^-) < 3.3 \times 10^{-4}$. In KLOE the signal is searched for the M(η) region of the $\pi^+\pi^-$ invariant mass spectrum of $\pi^+\pi^-\gamma$ events selected according to the $f_0(980)\to \pi^+\pi^-$ analysis described before (see fig. 1). The signal efficiency is: ϵ_s=16.6%. The expected signal has a Gaussian shape with a mass resolution of 1.33 MeV. No signal is observed. The background is determined by fitting the theoretical model for $\pi^+\pi^-\gamma$ sample to the full spectrum. In order to determine an upper limit, we have added to this background a Gaussian function representing the signal multiplied by a constant N_s. We obtain: $N_s = -8 \pm 24$. The 90% confidence level upper limit on the number of events is obtained using the tables in [17]: $N_s < 33$. The branching ratio is $BR(\eta \to \pi^+\pi^-) = \frac{N_s}{\epsilon_s N_\eta}$ with N_η the number of η in the sample (1.55×10^7). The 90% C.L. upper limit is: $BR(\eta \to \pi^+\pi^-) < 1.3 \times 10^{-5}$. It improves by a factor $\sim$ 30 the current PDG limit.

5 η- η' mixing

Here we present the $R = \frac{\Gamma(\phi\to\eta'\gamma\ )}{\Gamma(\phi\to\eta\gamma\ )}$ measurement. The η' is identified via the decays: $\phi \to \eta'\gamma$; $\eta' \to \pi^+\pi^-\eta$; $\eta \to \pi^0\pi^0\pi^0$ and the decays $\phi \to \eta'\gamma$; $\eta' \to \pi^0\pi^0\eta$; $\eta \to \pi^+\pi^-\pi^0$. The final state is thus charachterized by two charged pions and seven photons, and has no physics background with the same topology in KLOE. After background subtraction we observe $3405 \pm 61 \pm 31$ $\phi \to \eta'\gamma$ events. We normalize to the number of observed $\eta \to \pi^0\pi^0\pi^0$ decays in the same runs to obtain a preliminary measurement of the ratio of BR's: $R = (4.9 \pm 0.1_{stat} \pm 0.2_{syst}) \times 10^{-3}$.

This result compares favourably with our previous estimate [18] (which already dominates the world average [3]) but with considerably improved accuracy.

6 A new measurement of the ϕ leptonic width.

KLOE has performed a new measurement of the ϕ leptonic widths Γ_{ll} with $l = e, \mu$ [19], using the two data samples taken below ($\sqrt{s}$=1017 MeV) and above ($\sqrt{s}$=1022 MeV) the ϕ peak together with the data taken at the ϕ peak. The dependences on $\sqrt{s}$ of the forward-backward asymmetry of Bhabha events A_{FB} and of the $e^+e^- \rightarrow \mu^+\mu^-$ cross-section $\sigma(\mu\mu)$ around the ϕ peak are sensitive to the value of Γ_{ee} and $\sqrt{\Gamma_{ee}\Gamma_{\mu\mu}}$ respectively. We measure the ϕ mass M_ϕ, the forward-backward asymmetry at $W = M_\phi$ A^0_{FB}, and finally Γ_{ee}. The result for Γ_{ee} is: $\Gamma_{ee} = 1.32 \pm 0.05_{stat} \pm 0.03_{syst}$ keV The result for $\sqrt{\Gamma_{ee}\Gamma_{\mu\mu}}$ is : $\sqrt{\Gamma_{ee}\Gamma_{\mu\mu}} = 1.320 \pm 0.018_{stat} \pm 0.017_{syst}$ keV. The two results are in good agreement consistently with lepton universality. Combining them we get: $\Gamma_{ll} = 1.320{\pm}0.017_{stat}{\pm}0.015_{syst}\, keV$ with a total uncertainty below 2 %. We point out that the value of Γ_{ee} is necessary for ϕ decay branching ratio measurements, and play also a role in the evaluation of the hadronic contribution to vacuum polarization [20].

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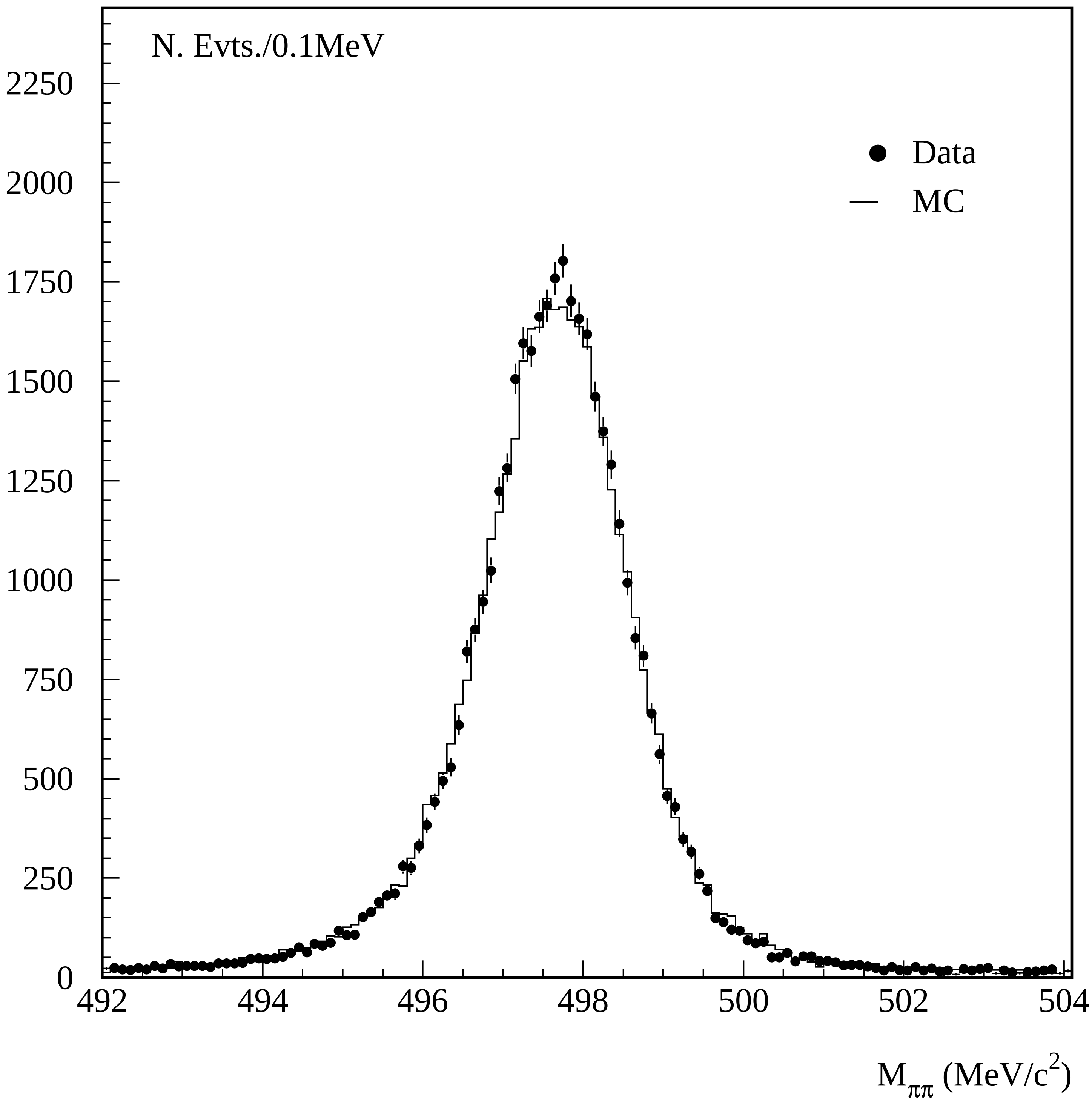
N. Evts./0.1MeV
2250
2000
1750
1500
1250
1000
750
500
250
0
492
494
496
498
500
502
504
Data
MC
$M_{\pi\pi}$ (MeV/c^2)